ELECTROMYOGRAPHIC INVESTIGATIONS IN MAN AT REST AND IN THE RECOVERY PERIOD AFTER WORK

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Despite numerous investigations indicating a connection between the total respiratory gas exchange and the activity of the muscular system, the question of the participation of the various groups of muscles in the maintenance of the level of the gas exchange in the intact organism remains unanswered. Investigations of this type may shed light on the role of the bioenergetics of muscle tone.

The recovery period after muscular work is especially interesting in this aspect, for by comparing the changes in the level of the gas exchange and the changes in the functional state of the muscles in dynamic studies, an idea may be obtained of the importance of the skeletal muscles in the process of regulation of the level of this exchange during the transition from physical activity to rest.

The object of the present investigation was to study the special features of the respiratory gas exchange and of the bioelectrical activity of the muscles in the human subject at rest, before muscular exertion, and immediately thereafter.

EXPERIMENTAL METHOD

Observations were made on three subjects aged 25-30 years. The muscular work (8 min) consisted of the performance of physical exercises (lifting dumbbells, flexing and extending the knees, climbing on to a stool and down from it, walking on the spot, and so on). The respiratory gas exchange, the pulse rate, and the electrical activity of the various muscles before, during, and after muscular work were studied. The gas exchange was investigated automatically by Bülow's electrical apparatus. The action potentials of the muscles and the pulse rate were recorded by means of a multichannel oscillograph as proposed by S. A. Evdokimov, V. V. Semenov, G. N. Sokolov, and V. A. Tarasov [2], incorporating electronic integrators for computing the total bioelectrical activity of the muscles during a definite time interval. The potentials were recorded in the biceps brachii, rectus femoris, obliquus abdominis, trapezius, latissimus dorsi, masseter, and sternocleidomastoideus muscles.

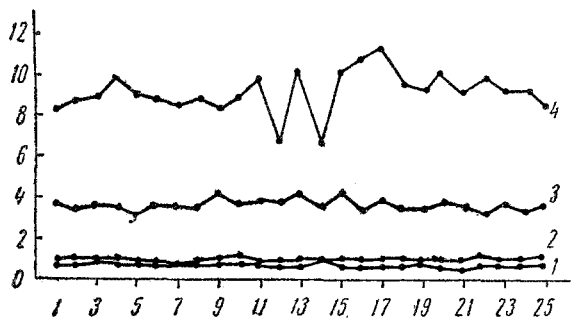

Fig. 1. Bioelectrical activity of various muscles at rest in recumbency. 1) Rectus femoris; 2) biceps brachii; 3) obliquus abdominis; 4) sternocleidomastoideus. Along axis of ordinates) bioelectrical activity (in μV/min); along axis of abscissas) duration of experiment (in min).

EXPERIMENTAL RESULTS

At rest, whether lying or standing, before the action of physical exertion, the bioelectrical activity in the limb (arm, thigh) muscles was very low, in agreement with the results obtained by other authors [3, 5, 7, 8]. In these experimental conditions the bioelectrical activity of the biceps brachii and rectus femoris muscles was 1.2 μV/min. In the muscles of the head and trunk a well marked flow of

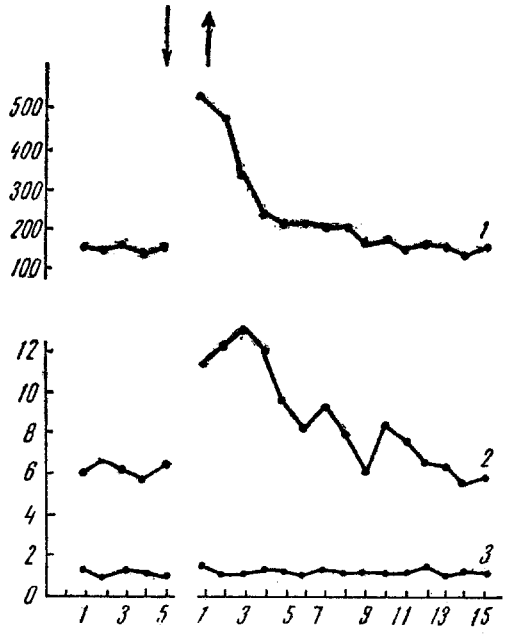

Fig. 2. Bioelectrical activity of muscles and gas exchange in subject T. before and after muscular work. 1) Oxygen demand; 2) bioelectrical activity of sternocleidomastoideus muscle; 3) bioelectrical activity of rectus femoris muscle. Along axis of ordinates) top curve, oxygen consumption (in ml/min), bottom curve, bioelectrical activity (in μg/min); along axis of abscissas) duration of experiment (in min). Arrow pointing downward) beginning of work; arrow pointing upward) end of work.

impulses was observed (Fig. 1). High electrical activity (4-9 μV/min) was detected in these circumstances in the sternocleidomastoideus muscle. The activity of the muscles of the jaws, the abdomen, and the spine was 2-5 μV/min. Whereas the level of the bioelectrical activity in the limb (arm, thigh) muscles was more ore less constant, the flow of impulses in the muscles of the head and trunk was very variable. The fluctuations in bioelectrical activity were especially great in the sternocleidomastoideus muscle (see Fig. 1).

In the recovery period, at the end of the work, regardless of the character of the preceding physical exertion and the position, the bioelectrical activity of the limb muscles, which had increased considerably during the period of activity (by 15-20 times or more over the resting level), returned to its original value observed in the resting state before the exercises (see table and Fig. 2). Sometimes the bioelectrical activity of the limb muscles returned to its original level within 1-2 min after the end of the muscular work. This may probably be explained by postulating that the working limbs did not resume their original position immediately after the physical exertion had ended.

The bioelectrical activity of the muscles of the head, neck, and trunk also increased during work (by 2-5 times over the original level), and in these conditions returned to the original level 5-10 min after the end of the muscular activity, or sometimes much later (see Fig. 2).

The changes observed in the bioelectrical activity of the muscles of the head and trunk in the period of recovery after work showed a correlation with the course of restoration of the respiratory gas exchange – the oxygen consumption (Fig. 2, 3) – but not with the course of restoration of the pulse rate (Fig. 3). Whereas the pulse rate returned to the preworking level approximately 1-2, and sometimes 3, minutes after the end of muscular activity, the oxygen consumption returned to its original level in the same conditions after 5-10 min. There are reports in the literature of differences in the time of recovery of the various functions of the body after muscular activity. According to the findings described by M. Ya. Gorkin and co-workers [1], L. I. Karpenko [4], and others, for instance, the cardiac activity is restored much sooner than the other functions. É. G. Martirosov and I. K. Sivkov [6] found that the blood pressure and pulse rate recover faster than the lactic acid concentration in the blood. The results of the experiments showed that the pulse rate was restored much faster than the overall respiratory gas exchange.

The duration of recovery of the overall gas exchange, although related to the changes in the pulse rate, reflected more closely the specific pattern of restoration of the intimate metabolic changes in the various organs and systems. In particular, an important role in its recovery was played by processes taking place in the muscular system, as illustrated by the results of observations showing that the course of recovery of the gas exchange coincided in time with the course of recovery of the bioelectrical activity of the muscles, although of the tonic postural muscles (the muscles of the head and trunk) and not of the locomotor muscles.

The changes in the gas exchange in the recovery period after light and moderately heavy muscular work were evidently associated with the participation mainly of the muscles of the neck, chest, and abdomen, i.e., of the tonic postural muscles maintaining the regulation of the tone at rest (the attitude of the body, the posture). The limb muscles (arm, thigh) exhibit activity only when the organism is engaged in activity, i.e., during the performance of locomotor acts. Immediately after the end of working, the bioelectrical activity of these muscles was very slight. Evidently the intermittently acting muscles do not play an essential role in the regulation of the level of the respiratory gas exchange in the recovery period after muscular work.

Bioelectrical Activity of Various Muscles Before and After Muscular Work (in μV)

Subject	Muscle	Before work, at rest (in min)					Character of work done	Recovery period after working (in min)														
		1	2	3	4	5		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
M.	Biceps (left arm)	1,40	1,51	1,60	1,54	1,28	Lifting dumbbells Flexing and bending knees	1,46	1,43	1,49	1,40	1,40	1,34	1,48	1,26	1,37	1,40	1,32	1,34	1,46	1,37	1,40
T.	Rectus (right femur)	0,87	0,84	0,72	0,75	0,74		0,93	0,81	0,78	0,86	0,92	0,81	0,85	0,81	0,89	0,81	0,84	0,92	0,84	0,84	0,85
L.	Biceps (right arm)	0,83	0,83	0,83	0,85	0,81	Walking on the spot	1,13	0,98	0,79	0,86	0,86	0,89	0,89	0,86	0,89	0,89	0,92	0,92	0,92	0,92	0,95
L.	Rectus (right femur)	0,95	1,01	1,01	1,07	0,98	" " "	1,22	1,01	1,04	1,04	1,04	1,01	1,01	1,01	0,98	1,04	1,01	0,92	1,04	0,98	1,04

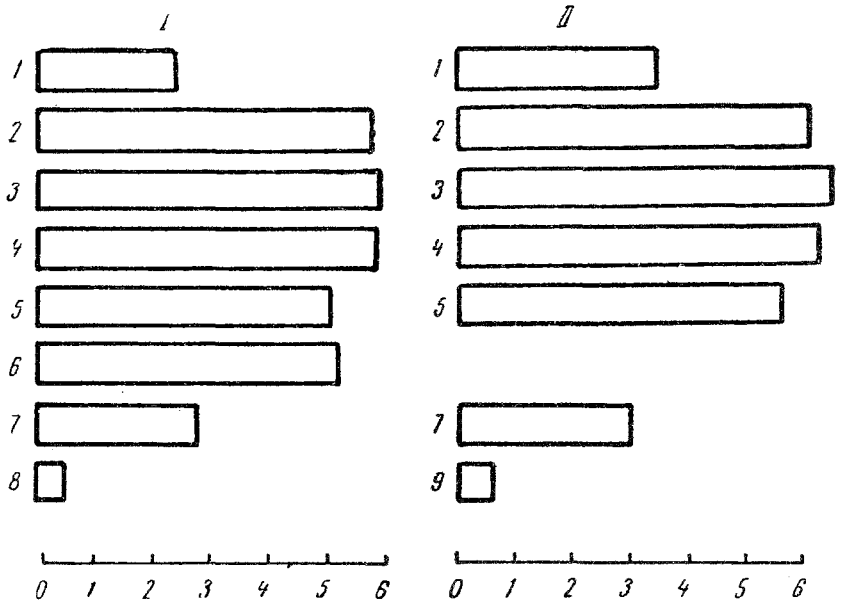

Fig. 3. Duration of recovery period of gas exchange, bioelectrical activity of muscles, and pulse rate after lifting dumbbells (I) and flexing and extending the knees (II). 1) Pulse; 2) oxygen consumption; 3) bioelectrical activity of sternocleidomastoideus muscle; 4) of masseter muscle; 5) of obliquus abdominis muscle; 6) of latissimus dorsi; 7) of trapezius; 8) of biceps brachii; 9) of rectus femoris. Along axis of abscissas) time of recovery (in min).

Facts have been obtained shedding light on the mechanisms of maintenance of the level of the gas exchange in the human subject at rest, and they enable the concept of basal metabolism to be examined from a new viewpoint. The differences in the pattern of change of tone of the locomotor and the tonic, postural muscles indicate the functional powers of the differences discovered in the muscle groups studied may be determined by specific differences in the chemical properties of the tonic and tetanic muscles.

SUMMARY

Data are presented throwing light on certain characteristics of the respiratory gas turnover and bioelectrical activity of various muscles in man at rest and in the restorative period after work of light and medium intensity.

Under the conditions of rest, before muscular loads, in the muscles of the extremities (shoulder, thigh) the bioelectrical activity is very low whereas in the muscles of the head, neck, and trunk is noted distinct pulsations. In the restorative period, upon completion of work irrespective of the character of the load, the bioelectrical activity of the muscles of the extremities which grows considerably during activity immediately (sometimes in 1-2 min in our investigations) is restored to its initial degree observed at rest before working. The bioelectrical activity of the muscles of the head, neck, and trunk is restored under these conditions somewhat later – in 5-10 min after the completion of work. These changes in the biolectrical activity of the posetonic muscles are correlated to the course of restoration of respiratory gas turnover (oxygen consumption).

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.
